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Comparison of Aircraft and DMSP SSM/I Passive Microwave Measurements Over the Bering Sea in April 1995

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Abstract - During April 1995 a NASA ER-2 high-altitude aircraft carrying a Millimeter-Wave Imaging Radiometer (MIR) made two flights over the Bering Sea as part of a mission to study sea ice and snow for improving retrievals of these parameters from passive microwave radiometers. MIR measures radiances at 89 GHz, 150 GHz, three frequencies near 183 GHz, and at 220 GHz. Sea ice features are observable at all frequencies except at 183 GHz, because of strong atmospheric water vapor absorption. The radiometric brightness over ice-free ocean increases with frequency as expected, but the situation is more complex over sea ice.

INTRODUCTION

A NASA ER-2 high-altitude aircraft made a series of flights over Alaska and the Bering Sea in April 1995 in support of sea ice and snow algorithm development for the NASA MTPE EOS AMSR and MODIS instrument science teams. The two primary sensors aboard the ER-2 were a six-channel, total power Millimeter-Wave Imaging Radiometer (MIR) and a Moderate Resolution Imaging Spectroradiometer Airborne Simulator. This paper reports on the results obtained with the MIR over the Bering Sea ice cover on April 8.

Sea ice retrievals from satellite passive microwave radiometers are sensitive to atmospheric water vapor variability. This is particularly the case in the vicinity of the ice edge and in marginal sea ice zones where ice concentrations are low. Some studies have examined the effect of water vapor variability on sea ice retrievals at lower frequencies (18 and 37 GHz) [1], but little work has been done at higher frequencies (85 GHz and higher). The MIR range of frequencies (89 GHz to 220 GHz) have been used previously for determining water vapor profiles over the ocean surface [2] and may, in combination with the lower frequency channels on the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I), also be useful in assessing and improving current methods of eliminating the effects of water vapor variability on sea ice retrievals [3]. This paper examines the spectral variation of MIR radiances over the Bering Sea ice cover and compares this variation to the known properties of the ice cover as determined from the DMSP SSM/I.

DATA

The DMSP SSM/I radiances are used with the NASA Team sea ice algorithms [4,5] to provide a description of the Bering Sea ice cover. On April 8 the ice cover extended to 55.6° N, 194° E in the southeastern portion of the Bering Sea and to 60° N, 180° E in the western portion. The sea ice concentration was generally high (85-100%), except in the marginal ice zone and in coastal polynyas. The largest coastal polynya was located south of St. Lawrence Island (SLI) where the minimum observed concentration at the mapped resolution of 25 km was 45%. From the NASA thin ice algorithm [5] only two areas along the aircraft flight path show the presence of new and young ice; one is a coastal polynya in the eastern most end of Norton Sound and the other is the SLI polynya.

The ER-2 MIR is a cross-track scanner that has a 3-dB beam width of 3.5° and an angular swath of 100°. At a nominal aircraft altitude of 18.5 km, the ground resolution at nadir is about 1 km. It measures a mixture of horizontal and vertical polarizations at 89 GHz, 150 GHz, 183±1 GHz, 183±3 GHz, 183±7 GHz, and at 220 GHz. The polarization mix varies with incidence angle, but this effect is small over sea ice. There is generally good agreement between the MIR 89 GHz observations and the averaged 85.5 GHz horizontally and vertically polarized DMSP SSM/I data. The ER-2 aircraft flight tracks over the Bering Sea were planned to optimize coverage of as many SSM/I footprints as possible while still imaging a range of sea ice types and ice-free ocean.

RESULTS

The April 8 MIR radiance maps for 89 GHz, 150 GHz, and 220 GHz are shown in Fig. 1, 2, and 3 respectively. These figures show sea ice areas which exhibit contrasting spectral variations along the flight path. The first is an area of consolidated sea ice off of Nome, Alaska. MIR brightness temperatures range from 190 K to 210 K at 89 GHz, from 175 K to 200 K at 150 GHz, and from 200 K to 210 GHz at 220 GHz. The lower radiances observed at 150 GHz are not consistent with the expected increase in brightness with frequency resulting from atmospheric water vapor emission. Examination of the 85 GHz SSM/I data at horizontal and vertical polarization also shows this area of relatively low brightness. This is not observed,

Figure 1: MIR 89 GHz image of the Bering Sea ice cover for April 8. 1995.

however, at lower frequencies or in the polarization, (V-H)/(V+H), at 85 GHz. This decrease in brightness at 150 GHz relative to the other two MIR frequencies is also observed in the region just north of SLI.

In contrast to this spectral variation is the increase in brightness temperature with frequency observed in the polynya south of SLI (see Fig. 1, 2, and 3). Near the SLI coastline, the MIR brightness temperatures increase from about 200 K at 89 GHz, to 220 K at 150 GHz, and to 240 K at 220 GHz. The spatial pattern of radiances observed in the figures suggests the presence of clouds (or water vapor) emanating from over the polynya and spreading southward. This is not inconsistent with a characteristic feature of polynyas. An increase in brightness with MIR frequency is also observed farther south in the marginal ice zone, a transition region of lower ice concentration, and over ice-free ocean.

CONCLUSIONS

The contrasting spectral variations observed in MIR data at 89, 150, and 220 GHz over the Bering Sea ice cover on April 8 suggest that both atmospheric emission and surface influences are affecting the received radiances. In a region off of Nome, Alaska and just north of SLI, the lower brightness at 150 GHz relative to the other two frequencies suggests the occurrence of surface scattering. This scattering may result from a particularly heavy snow cover on the sea ice. This effect has been observed north of SLI in previous aircraft missions [6]. Over ice-free ocean or areas of low ice concentration, as for example, in the vicinity of coastal polynyas, the increase of brightness temperature with frequency is consistent with a spectral response one would expect from an atmosphere with appreciable water vapor. Further work is needed to determine quantitatively the contributions from surface scattering and atmospheric water vapor variability.

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Figure 2: MIR 150 GHz image of the Bering Sea ice cover for April 8, 1995.

Figure 3: MIR 220 GHz image of the Bering Sea ice cover for April 8, 1995.